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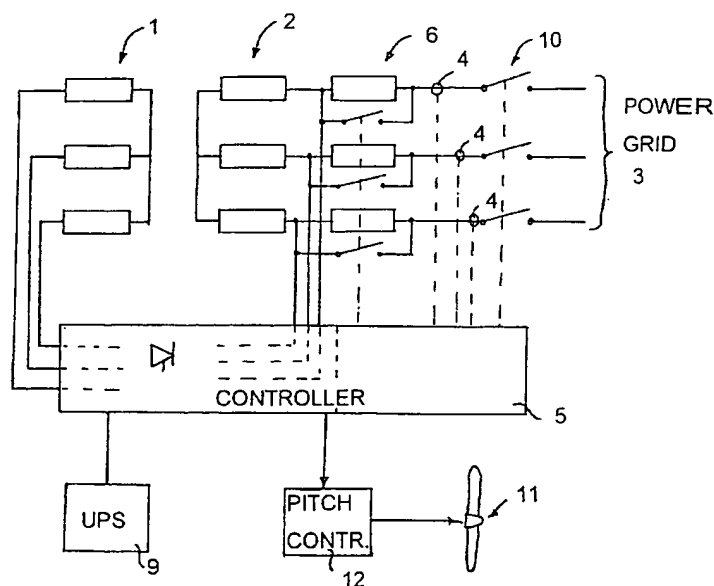
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(54) Title: POWER GRID CONNECTION SYSTEM FOR A WIND TURBINE GENERATOR



(57) Abstract: A power grid connection system for a wind turbine generator comprises a wind turbine driven rotor (1) and a stator (2) connected to supply electrical power to the power grid (3). An electrical transient detection device (4) for delivering signals to a controller (5), and a number of current limiters (6) in the form of controlled impedances connected between the power grid (3) and said generator, said current limiters (6) being activated by the controller (5) in dependence of the detection of the electrical transients, provide a system capable of keeping the wind turbine generator connected to the power grid (3) during power grid faults and thus take active part in the stabilization of the power grid (3).

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POWER GRID CONNECTION SYSTEM FOR A WIND TURBINE GENERATORTECHNICAL FIELD

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The present invention relates to a power grid connection system for a wind turbine generator of the kind set forth in the preamble of claim 1.

10 BACKGROUND ART

In power grid connection systems for wind turbine generators of this kind, it is known to connect the generator directly to the power grid through a disconnecting device, which disconnects the generator from the power grid in case of the power grid being  
15 subjected to a fault situation, such as a short circuit. The normal procedure for reconnecting such a wind turbine generator has been to stay disconnected until the power grid is stabilized after fault clearance.

The disadvantage of this procedure is that the wind turbine generator cannot take an  
20 active part in stabilizing the network into a steady state, such stabilization thus being dependent on other types of generators being able to supply the necessary power to stabilize the power grid before reconnecting the wind turbine generators. Due to the penetration of wind energy in the power grid, there is thus a demand for the wind turbines to be able to take active part in production of electrical power during power  
25 grid failure and contribute to a higher steady state short circuit current.

DE-A-3,213,793 describes a grid system comprising several generators and a detection circuit for detecting fault conditions in the grid. In case of a fault in the grid, the grid is separated into two sections each comprising a group of generators, and one  
30 group of generators can be operated in an almost normal condition, the separation limiting the current drawn from this group to the fault-containing group by means of suitable impedances, and the reconnection is facilitated by the maintenance of synchronization through the impedances. Nothing in this document indicates the possibility of using such a system of separating impedances for each individual  
35 generator connected to the grid system. The impedances are thus not connected

between a generator and the grid, but between two parts of the grid, each part comprising a group of generators.

## 5 DISCLOSURE OF THE INVENTION

It is the object of the present invention to provide a power grid connection system for a wind turbine generator of the kind referred to above, with which it is possible to keep the wind turbine generator connected to the power grid during power grid faults and  
10 thus take active part in the stabilization of the power grid immediately under and after fault clearance. This object is achieved with a power grid connection system for a wind turbine generator of said kind, which according to the present invention also comprises the features set forth in the characterizing clause of claim 1. With this arrangement, the wind turbine generator system is protected from the electrical transients during a  
15 fault situation on the power grid by means of the current limiters and is taking active part in stabilizing the power grid, and the wind turbine provides a short circuit contribution during such fault situations. For standard asynchronous machines, it is known that no steady state short-circuit current contribution exists. With this invention implemented on a wind turbine with asynchronous generator, the asynchronous  
20 generator will contribute to the steady state short-circuit current level, and contribute to tripping the protective equipment of the power grid system. Furthermore, wind turbine overspeed is also limited due to the fact that the short circuit power level is increased by introducing the current limiters and the electrical torque is thus maintained at a certain level. This will also reduce the mechanical stress on the turbine, as the  
25 dynamic torque change is limited.

## BRIEF DESCRIPTION OF THE DRAWING

30 In the following detailed part of the present description, the invention will be explained in more detail with reference to the exemplary embodiment of a power grid connection system for a wind turbine generator according to the invention shown in the drawings, in which

Figure 1 shows a schematic diagram of a power grid connection system for a wind  
35 turbine generator in accordance with a preferred embodiment, and

Figure 2 shows a more detailed schematic diagram of the current limiter 6 used in Figure 1.

## 5 DESCRIPTION OF THE PREFERRED EMBODIMENT

The power grid connection system for a wind turbine generator shown in Figure 1 comprises a wind turbine driven rotor 1 with rotor windings and a stator 2 with stator windings connected to supply electrical power to the power grid 3. The generator  
10 shown in Figure 1 is an asynchronous generator with variable speed, in which the electrical power generation is governed by a controller 5, by controlling the current in the rotor windings. Naturally, the invention can be used in connection with other types of generators such as synchronous generators, switched reluctance generators, etc., and in any situations where the transient currents should be limited.

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In the embodiment shown, the controller 5 is connected to an uninterruptible power supply 9 and to a pitch control 12 controlling the pitch of the blades of the wind turbine rotor 11. The wind turbine rotor 11 is connected to the generator rotor 1, possibly through a gear train for converting the slow rotation of the wind turbine rotor 11 to the  
20 fast rotational speed of the generator rotor 1. By suitable control of the current in the rotor windings performed by the controller 5, the stator windings and rotor windings will deliver electrical power to the power grid through the current limiters 6 and the main contactor 10. Suitable current measuring devices 4 are connected to measure the current delivered in each phase of the power grid 3 from the generator and for  
25 delivering current signals to the controller 5. The current limiters 6 are controlled from the controller 5, i.e. the current limiters are activated or deactivated, in dependence of the received current signals from the current measuring devices 4. Furthermore, measurement of voltage and frequency can be used for deciding activation and deactivation of the current limiters, said measurements being performed to detect  
30 transient electrical patterns indicating the occurrence of a fault in the grid and clearance of the fault, respectively.

In a preferred embodiment, the current limiters 6 comprise series impedances 7 in parallel with power electronic switches 8, as shown in Figure 2, said power electronic  
35 switches 8 being controlled by the controller 5 in order to electrically short-circuit the

series impedances 7 in dependence of the received current signals from the current measuring devices 4, and further measurements, as indicated above.

During normal operation, i.e. when no faults are present on the power grid 3, the power electronic switches 8 are triggered to electrically short-circuit the series impedances 7 and the generator supplies electrical power to the power grid 3, said power being controlled by the controller 5 by controlling the current in the rotor windings and the pitch of the blades of the wind turbine rotor 11. If the current detected by a current measuring device 4 increases above a predetermined level, or further measurements indicate the occurrence of a fault, the controller 5 activates the corresponding current limiter 6, i.e. the triggering of the power electronic switches 8 is discontinued and accordingly the series impedance 7 is connected in series with the corresponding phase, whereby the current in this phase is limited and the generated electrical power is dissipated in said series impedance 7. In the system shown in Figure 1, it is possible to activate and deactivate the individual current limiters 6 in accordance with the corresponding measured current, or other measurements, in the individual phases. The activation of the current limiters 6 provides the following advantages:

- i) the generator system, i.e. generator and associated electrical components, is protected from electrical transients during the fault situation on the power grid,
- ii) the generator provides a short-circuit contribution to the power grid 3 during the fault situation,
- iii) the wind turbine is protected against overspeed due to the power consumption of the series impedance 7 increasing the short-circuit power level and thus maintaining the electrical torque on the generator at a certain level, and
- iv) the mechanical stresses on the wind turbine are reduced due to the limitation of the dynamic torque changes.

Furthermore, the wind turbine generator is able to contribute to the stabilization of the power grid 3 during the fault situation and it is possible to control the wind turbine to deliver a controlled power during the fault situation until the power grid voltage is re-established, and direct power control after the fault is cleared.

The power electronic switches can be any kind of such switches ensuring a short response time and switching is performed using e.g. a comparator or estimator,

whereby the control delay from reaching the maximum current level or other measurement indicating the occurrence of a fault until the impedance is switched in can be minimised. Furthermore, a monitoring system is installed to provide reconnection functionality to normal operation when the fault is cleared. The monitoring system will also handle the control of the rotor winding current. By detecting the over current in each phase, it is possible only to add impedance in phases with over current in case of asymmetrical faults. The power electronic switches 8 introduce additional losses due to the fact that during normal operation they are conducting the current delivered to the power grid, but these losses are estimated to be approximately 0.5% of the overall production.

The voltage at the generator terminals is maintained due to the turbines' ability to maintain a power production through the increased fault impedance. This voltage is controlled in phase and amplitude by the controller 5. The uninterruptible power supply 9 ensures the control functionality even if the terminal voltage drops to a low level. During the fault condition, the controller 5 will change state from controlling constant power to controlling the stator voltage phase and frequency according to the voltage reference before introducing the fault. Preferably the control system will prepare the reappearance of the network voltage during fault condition and control the current to the lowest possible level in order to minimize the influence of the returning network voltage. During the fault condition, the power control is thus disabled, enabling voltage control with a fast current controller. When the voltage returns, the impedance will be decreased as to return to normal operation conditions and the reconnection will be performed during the current zero crossing in order to minimize the influence of the reappearance of the network voltage, whereupon the control system returns from voltage control to power control resuming the pre-fault power level.

The turbine control system is able to run through electrical transients as long as the hardware limits of the generator and its electrical equipment are not reached, which can be ensured by the current-limiting function. In this way, the turbine is able to supply a continuous power and accordingly a short circuit contribution, which may be requested by the power grid 3 in order to assure tripping of the protective relays in order to isolate the faulty parts from the power grid 3.

It is a primary goal to keep the turbine online during a fault and get back to pre-fault operation as fast as possible after the fault is cleared. Thus, the invention limits

electrical transients and avoids the necessity of disconnecting the turbine generator from the power grid 3.

In the foregoing, the invention has been described in connection with a preferred  
5 embodiment and several modifications can be envisaged within the scope of the following claims.

CLAIMS

1. Power grid connection system for a wind turbine generator, comprising a wind turbine driven rotor (1) and a stator (2) connected to supply electrical power to the power grid (3), characterized by comprising an electrical transient detection device (4) for delivering signals to a controller (5), and a number of current limiters (6) in the form of controlled impedances connected between the power grid (3) and said generator, said current limiters (6) being activated by the controller (5) in dependence of the detection of the electrical transients.
2. System in accordance with claim 1, characterized by the electrical transient detection device (4) comprising a current measuring device (4) in each phase for delivering current signals to the controller (5).
3. System in accordance with claim 1 or 2, characterized by said current limiters (6) comprising series impedances (7) in parallel with power electronic switches (8) for electrically short circuiting the series impedances (7) in dependence of the detection of the electrical transients.
4. System in accordance with claim 1, 2 or 3, characterized by the current limiters (6) being connected in series with the power grid (3) connections and activated individually in dependence of the detected electrical transient signals.
5. System in accordance with any of the preceding claims, characterized by the controller (5) being supplied with power through an uninterruptible power supply (9) (UPS).
6. System in accordance with any of the preceding claims, characterized by further comprising a monitoring system for initiating reconnection to normal operation, i.e. with current limiters (6) deactivated, when current measurements and/or corresponding voltage measurements and/or the electrical transient detection device (4) indicate that normal operation can be resumed.

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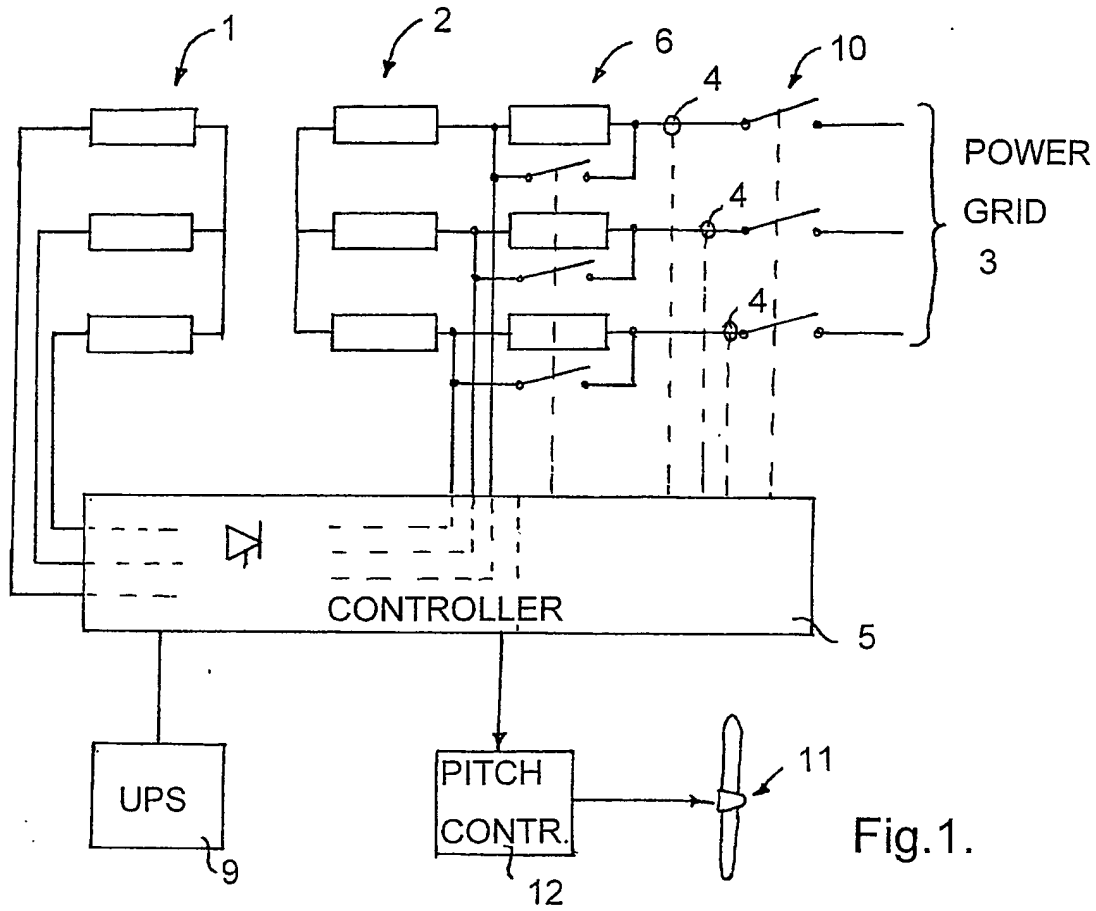


Fig.1.

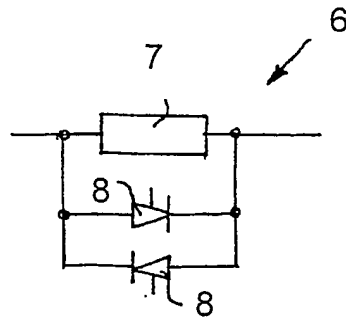


Fig.2.

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/DK 02/00841

**A. CLASSIFICATION OF SUBJECT MATTER**  
 IPC 7 H02H7/06

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H02H H02P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 41 35 367 A (ROHATSCH KLAUS) 14 May 1992 (1992-05-14) abstract; figure 1 ----	1-6
Y	GB 1 107 870 A (LICENTIA GMBH) 27 March 1968 (1968-03-27) claims 1,2,5,6; figure 1 ----	1-6
A	WO 96 13091 A (KENETECH WINDPOWER INC) 2 May 1996 (1996-05-02) page 8, line 1 -page 10, line 2; figure 4A -----	1-6

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

\* Special categories of cited documents :

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/DK 02/00841

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